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Agenda Toward the Development of a Rational Noise Descriptor System Relevant to Human Annoyance by En Route Aircraft Noise.

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Introduction.

A rational, internationally consistent, noise descriptor system is needed to express existing and predicted en route aircraft noise levels in terms closely correlated to the annoyance perceived by people and physiologically identifiable in people, to provide guidance for

- aircraft and powerplant design,
- flight management,
- land-use planning, and
- building codes.

Expanding on previous discussions (Refs. 1, 2, 3, and 4), the present paper seeks to provide a new comprehensive statement of the specific questions that must be resolved by needed research, and the nature and quality of proof that must be adduced to justify further steps toward the drafting and adoption of new international en-route aircraft-noise standards.

The single noise-descriptor system envisioned must be valid for widely varying aircraft-noise frequency spectra, including time-variant components and "*agreeable*" and "*disagreeable*" discrete tones and combinations of tones.

The measures and criteria established by the system must be valid

- at high and low immission levels,
- at high and low ambient noise levels,
- for great and small numbers of noise events, and
- outdoors and indoors.

Historical Background.

Some of the objectives traced herein have attracted numerous individual scientific cause-and-effect, statistical, socio-economic, and legal investigations to date.

Yet, there has not been any coordinated international effort to translate the results of individual scientific investigation into a single internationally standardized aircraft noise descriptor system, the need for which is especially urgent for en route aircraft noise which can and does span international boundaries.

Governmental regulatory systems in various countries have formalized diverse "*frozen*" conceptual schemes which have served as the basis for decisions that have affected property rights and the quality of life of humans and animals.

In seeking to develop an advanced aircraft-noise descriptor system, it must be borne in mind that decisions made in accordance with existing government regulations and pursuant to forensic adjudications based on reliance on existing formally adopted descriptors have established formidable precedents that may not readily yield to new definitions, rules, and decisions.

Hence, the proof advanced for any new proposals must be rational and persuasive in light of human experience.

Aircraft noise, in the past and at this time, has been measured and assessed in terms of

(1) the maximum sound-pressure level and/or the total-energy noise-exposure level of a single event,

(2) the equivalent noise level over a stated period of time (for example, one hour), and

(3) the equivalent noise level (L_{eq}) over an entire circadian (24-hour) period, weighted by day and night penalties (L_{dn}) or day-evening-night penalties (CNEL), with sound-level weight factors that are related to periods of human recreation and rest.

Investigations by E.-A. Müller, K. Matschat, and U. Isermann have shown a high degree of correlation between various measures of such types for many aircraft-noise configurations in the environs of a busy airport. Yet, there remains an element of human differentiation between situations in which a numerical value of the circadian L_{eq} might vary little, but in which some specifics of the aircraft noise and the spatial and timewise variation of its characteristics may convey a different message to the affected citizen.

Numerous research undertakings on airport-related noise descriptors have been performed and reported in recent literature. Relatively little has been done with specific application to en-route aircraft noise, the importance of which, long disregarded, is now becoming apparent.

Thus, there still remains a need for a coordinated effort to establish specific goals for studies, criteria for the nature and quality of verification and proof, and assessments of the problems to be overcome in the use of the results of research for administrative implementation. From the outset, a survey of existing administrative aircraft-noise criteria applicable to the impact on humans and animals by en route aircraft noise in various countries is advisable; such survey should reveal not only the criteria that different countries are actually implementing, such as

was done in Ref. 5, but the reasons adduced for such implementation and the scope of current pertinent research efforts.

Definition of the Term "En Route" in "En Route Aircraft Noise."

The current FAA-NASA Symposium affords perhaps the first opportunity for scientists, technicians, and regulators to examine the problem of en route aircraft noise in a formal, dedicated, setting.

Whereas the general meaning of the term "*en route*" might be intuitively understood, it is suggested that a precise formal definition of the term "*en route*" would be opportune from the outset, especially since the scientific and technical investigation of the problem of noise immissions on the ground from aircraft in flight away from the airspace of an airport may conceivably lead to administrative, regulatory, and legal consequences that would mandatorily require a precise definition of the term "*en route*."

That definition, for pragmatic reasons, should afford a precise differentiation of the various segments of en route flight in which noise emissions at the source and noise immissions on the ground, are variously affected by airframe configuration, airspeed, powerplant operation, aircraft trajectory, and atmospheric transmission, refraction, and absorption.

A pertinent definition of the term "*en route*" is proposed in Ref. 6.

Research Goals and Quality of Proof.

The following specific aircraft-noise-related elements relating to en route aircraft noise require clarification at this time:

1. Shall sound-pressure levels or sound-power levels be employed and stated?
2. Is any single schematically ("linear," "A," "C," etc.) weighted sound-pressure level adequate to represent degrees of human annoyance at various numerical levels (Ref. 7), for noises comprising different frequency distribution,

for noises comprising one or more discrete intrusive tonal frequencies, and for noises subject to short-period or long-period fluctuations, all at high and low ambient noise levels?

3. Is it legitimate to attach "*patches*" to schematically weighted sound-pressure levels to account for varying frequency distributions and inclusion of one or more intrusive tonal frequencies and time fluctuations?

4. Can integrative single-event noise exposure values (SEL/SENEL) based on an A-weighted sound-pressure level be "*patched*" to allow for annoyances generated by varying frequency spectra by using "*effective*" threshold-exceedance durations as a form of energy corrections for aircraft noises incorporating intense low-frequency components?

5. Should aircraft-noise assessment be based on, or at least include, a measure that evaluates the entire frequency spectrum, duration and time-variancy elements, of single noise events? Can "*loudness*," expressed in sones (Refs. 7, 8, 9) serve as such a universal measure? Can such a measure be correlated reliably with the magnitude of the EPNL employed in aircraft certification (Ref. 10)?

6. Can meaningful expressions for circadian "*effective cumulative average*" noise levels be derived from the measure of single-event "*loudness*" and "*effective perceived noise level*"?

7. What "time-of-day" allowance or weight should be given to single-event noise levels or hourly or circadian "*effective cumulative average*" noise levels? After careful consideration, the State of California (Ref. 11) is currently renewing its preference for a "*weight-three*" assessment of noise events during the evening hours (1900-2200 local time), a decision that may create problems on a federal level through its inconsistency with the federally endorsed omission of any evening weight in many of its administrative and financial decisions affecting properties located near airports.

Concurrently, the Danish parliament has adopted the same "*evening*" weight of "*three*" for administrative and financial decisions in areas adjacent to airports (Ref. 12). Both Denmark and California continue to use a tenfold weight for nighttime noise events. In addition to the problem of the "*evening*" weight, two questions remain to be answered:

(7-a) Are identical weights to be used for all nighttime hours (2200-0700 local time)?

(7-b) Should identical weights be applied regardless of the magnitude and duration of the exceedance of single-event noise levels over the ambient noise level?

8. Going beyond the concept set forth in Appendix D of Ref. 13 and in Ref. 14, the State of California has experimented with a form of "*normalization*" of observed single-noise-event noise levels and circadian CNELs with reference to the prevailing ambient noise level (Ref. 15). Such reasonings may be of even greater significance in assessing human annoyance over en route aircraft noise in otherwise quiet areas than in urban areas directly adjacent of airports. It is possible, in this respect, that substantial differences in the criteria might arise in different societal cultures?

9. Can a single tolerable limit for a cumulative noise-exposure level be established for single noise events with differing frequency distributions and time-variance characteristics? Can such cumulative noise levels be generalized to a circadian 24-hour time period?

10. How is the tolerable maximum value of the cumulative circadian noise-exposure level of en-route aircraft noise events affected by the otherwise prevailing ambient background level?

11. Can that tolerable value be stated validly for the outdoor ambient alone, or should it apply to the noise immission at a person's ear during a day of activities partly outdoors, partly indoors? It is not clear, from the contents of

Ref. 13 and the recollection of its co-authors, whether the "tolerable" Ldn of 55 dB was referred to an exterior or an "at the recipient's ear" noise level.

12. What is the maximum tolerable single-event value of the selected form of aircraft noise descriptor? What is the smallest number of such "dominant" noise-descriptor levels at which the single-event noise levels and not the time-averaged "equivalent" noise level is representative of the annoyance perceived? (See also Ref. 16.)

13. For numbers of noise events at which the time-averaged "equivalent" value is deemed to be representative of annoyance, what is an appropriate "noise-equivalence" factor for the relationship between the number of events observed and the "equivalent noise level"? It has been observed that a 3-dB increase in actual maximum single-event noise levels and single-event noise-exposure levels is barely perceived by most observers, whereas a doubling in the number of dominant noise events is perceived and complained about by many people as "twice-as-much noise."

Usage in the United States and many other countries relies on a 3-dB increase in Leq, that is, ten times the decimal logarithm of two for a doubling of the number of dominant noise events. The Federal Republic of Germany has experimented with a 4-dB increment for a doubling of the number of dominant noise events.

The "number-equivalence" factor in terms of dB should be re-examined as a function of its pertinence to the degree of human annoyance, especially with reference to en-route noise events of relatively extremely long duration.

14. How can an "agreeable" or "acceptable" discrete-frequency (or narrow-band) sounds be defined? What is the exceedance level of such discrete tones over the level of an otherwise continuous frequency spectrum or a disagreeably perceived conglomerate of droning or rat-

tling sound, at which even an individually "acceptable" discrete tone is perceived as "disagreeable" or "unacceptable" Ref. 17)?

Here it should be noted that atmospheric attenuation of low-frequency noise is relatively tenuous, so that sound levels are relatively little reduced by increases in flight levels.

17. How can "agreeable-acceptable" and "disagreeable-unacceptable" dual or multiple tones be defined, especially with reference to the arising of beat frequencies therefrom?

18. In light of the impaired acoustical isolation properties of ordinary construction materials, especially for residential dwellings, against low-frequency noise components, can practicable specifications for such construction materials be established for habitable areas exposed to en route noise immissions embodying different and time-variable frequency spectra?

19. Can frequency and measurable noise-level criteria be established for the acceptability of secondary noise emissions in dwellings that are excited by exterior noise immissions? Can construction criteria be developed to provide for the avoidance of such objectionable interior secondary noise emissions?

20. Can analytical and projective methods be developed to assess and predict the effects of topography, such as valleys and planar and amphitheater-like configurations of hill slopes on the intensification, repetitive immission, and duration of en route aircraft noise events?

21. What is an adequate specification for the level of proof required to test the validity of a newly established aircraft noise descriptor system both with reference to an existing noise situation and for the prediction of a planned, but not yet existing noise situation? How can the quantitative meaning of a representative standard aircraft noise descriptor system be expressed in terms understandable to an intelligent, but not scientifically specialized, layman?

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